15-60 HZ QPO AND PERIASTRON PRECESSION AROUND THE X-RAY NEUTRON STAR MAGNETOSPHERE

C.M. ZHANG

IFT, UNESP, Rua Pamplona 145, 01405-900, Sao Paulo, Brasil
E-mail: zhangcm@ift.unesp.br

Based on the periastron precession model to account for kHz QPO of the binary X-ray neutron star, proposed by Stella and Vietri, we ascribe the 15-60 Hz Quasi Periodic Oscillation (QPO) to the periastron precession frequency of the orbiting accreted matter at the boundary of magnetosphere-disk of X-ray neutron star (NS). The obtained conclusions include: all QPO frequencies increase with increasing the accretion rate. The theoretical relations between 15-60 Hz QPO (HBO) frequency and the twin kHz QPOs are similar to the measured empirical formula. Further, the better fitted NS mass by the proposed model is about 1.9 solar masses for the detected LMXBs.

1 The Model

On the kHz QPO mechanism[1], recently, the general relativistic periastron precession effects are paid much attetion to account for kHz QPOs proposed by Stella and Vietri[2], which can explain the varied kHz QPOs separation $\Delta\nu$. Moreover, HBO frequency[3] ($\nu_{\rm HBO} \simeq 15 - 60$Hz), is interpreted to be the beat frequency between the Keperian frequency of the magnetosphere-disk and the stellar spin frequency [4]. Later, it was considered to be the nodal precession [5] of Lense-Thirring effect in the disk. In the model of SV99 [2], the twin kHz QPOs are ascribed to the Keperian frequency and the periastron frequency of material orbiting the neutron star at some disk radius, i.e., $\nu_2 = \nu_K = (M/4\pi^2 r^3)^{1/2}$ and $\nu_1 = \nu_K[1 - (1 - 6M/r)^{1/2}]$, where r is the Schwarzschild coordinate distance and M is the gravitational mass of neutron star (We set the unity of the speed of light and the gravitational constant $c = G = 1$). Here, we concentrate on the explanation of HBOs (for Atoll sources, 15 - 60 Hz QPO is supposed to be the same mechanism as HBO of Z sources [6] and its relation to the twin kHz QPOs. We assume that $\nu_{\rm HBO}$ is a periastron precession frequency of the accreted orbiting materials in the magnetosphere-disk boundary, and the twin kHz QPOs are that proposed in SV99[2] are produceed in the inner disk. There exists a scaling factor to connect two radii, which will be determined by the well fitted data of kHz QPO and HBO. Therefore, these basic frequencies are written as follows through defining the suitable parameter y, which is the ratio between the Schwarzschild radius to the disk radius,

$$\nu_1(y) = (1 - \sqrt{1-3y}) \times \ \nu_2(y) \ , \tag{1}$$

$$\nu_2(y) = \nu_o y^{3/2} \ , \quad \nu_o \equiv \frac{11300}{m} \ (Hz) \ , \tag{2}$$

$$\nu_{\rm HBO}(y) = \nu_o(1 - \sqrt{1-3\phi y}) \times (\phi y)^{3/2} \quad , \quad \phi \equiv \frac{r}{R_M} \ , \tag{3}$$

where R_M is the radius of NS magnetosphere, which is inversely related to the accretion rate and proportionally related to the magnetic field strength of the star.

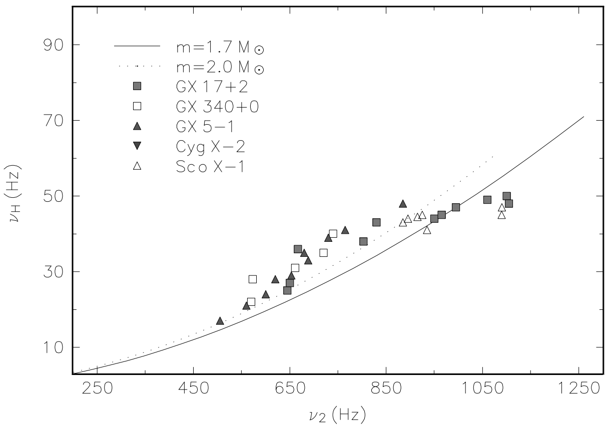

Figure 1. HBO frequency versus the upper kHz QPO frequency for five Z sources of LMXBs [6]. Error bars are not plotted for the sake of clarity. The model presents a well fitting for the nearly circular orbit of NS mass about 2.0 solar mass with the scaling parameter $\phi = 0.4$.

ϕ is a scaling parameter to connect the radii of the inner disk and NS magnetosphere, but here we suppose it to be $0.3 \sim 0.4$ for the reason of the best fitting.

The relations $\nu_{\rm HBO}$ vs. ν_2 is plotted in Fig.1, together with the well measured five Z-source samples, and it is shown that the agreement between the model and the observed QPO data is quite well.

From Eqs.(1), (2) and (3), we can derive the theoretical relations between QPO frequencies in the following,

$$\nu_{\rm HBO} \simeq 50.6\ (Hz)\ (\frac{\nu_1}{500})[1 - 0.15(\frac{m\nu_1}{500})^{2/5}]\ , \tag{4}$$

$$\nu_{\rm HBO} \simeq 30.4\ (Hz)\ m^{2/3}(\frac{\nu_2}{1000})^{5/3}[1 + 0.07(\frac{m\nu_2}{1000})^{2/3}]\ , \tag{5}$$

$$\nu_1 \simeq 300\ (Hz)\ m^{2/3}(\frac{\nu_2}{1000})^{5/3}[1 + 0.2(\frac{m\nu_2}{1000})^{2/3}]\ . \tag{6}$$

These theoretical relations are consistent with the empirical relations in ref.[6].

References

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